

What is claimed is:

1. A control device for controlling a fuel injection valve comprising:

an auxiliary power supply for stepping up voltage from  
5 a main power supply mounted on a vehicle;

a first switching element for conducting voltage from said auxiliary power supply to an electromagnetic solenoid for driving a fuel injection valve;

a second switching element for conducting voltage from  
10 said main power supply to said electromagnetic solenoid;

a third switching element that possesses a withstanding voltage limiting characteristic larger than a maximum output voltage from said auxiliary power supply, and interrupts a supply current to said electromagnetic solenoid at a high  
15 speed;

current detection means for detecting conduction current to said electromagnetic solenoid;

valve-opening signal generation means for inputting an operation information of an internal combustion engine and  
20 outputting a valve-opening signal and a valve-opening drive signal corresponding to a valve-opening time and a valve-opening time period of said fuel injection valve; and

conduction control means for controlling a power feed to said electromagnetic solenoid in response to a signal of  
25 said valve-opening signal generation means;

wherein said conduction control means performs a rapid power feed from said auxiliary power supply to said electromagnetic solenoid by means of said first switching element in response to the valve-opening drive signal from  
30 said valve-opening signal generation means;

said conduction control means performs a continuous power feed from said main power supply by means of said second switching element;

5       said conduction control means performs a hold power feed under ON/OFF control of said second switching element by feedback control based on a current value detected by said current detection means during continuance of said valve-opening signal after said valve-opening drive signal has ended;

10       said conduction control means interrupts a power feed to said electromagnetic solenoid at a high speed by means of said third switching element immediately after said valve-opening signal has ended; and

15       minimum value of an output voltage from said auxiliary power supply is set to be larger than a maximum value of voltage of said main power supply, and a step-up operation of said auxiliary power supply is stopped during said rapid power feed.

20       2. The control device of a fuel injection valve according to claim 1,

      wherein said auxiliary power supply comprises an induction element to which an electric power is fed from said main power supply via an exciting switching element and a capacitor for charging a voltage generated at said induction  
25    element due to open circuit of said exciting switching element; and said exciting switching element comes to be OFF and the capacitor stops charging when voltage of said capacitor has reached a predetermined value and during continuance of said valve-opening drive signal being a sum of said rapid power  
30    feed and said continuous power feed.

3. The control device of a fuel injection valve according to claim 1, further comprising rapid power feed detection means for detecting said rapid power feed;

5        wherein said rapid power feed detection means is constituted of a comparator that compares a first voltage proportional to a voltage at said main power supply with a second voltage proportional to an output voltage from said first switching element and outputs a rapid power feed  
10        detection signal when said second voltage becomes larger than said first voltage;

         and said exciting switching element is brought into a OFF state to stop a step-up operation in response to an input of said rapid power feed detection signal.

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4. The control device of a fuel injection valve according to claim 1,

         wherein, on the assumption that a holding current conducted to said electromagnetic solenoid at the time of said  
20        holding power feed is  $I_h$ ; a wire wound resistance of said electromagnetic solenoid is  $R$ ; a holding voltage applied to said electromagnetic solenoid at the time of conducting said holding current is  $V_h = I_h \times R$ ; an average voltage of said auxiliary power supply applied to said electromagnetic  
25        solenoid at the time of performing said rapid power feed is  $V_{pa}$ ; and voltage of said main power supply applied to said electromagnetic solenoid at the time of performing said continuous power feed, a relation among respective applied voltages satisfies the following expression:

30         $(V_{bmax}/V_h)^2 > (V_{pa}/V_h) > (V_{bmin}/V_h)^2$

5. The control device of a fuel injection valve according to claim 1,

wherein a first switching element for performing a rapid  
5 power feed from said auxiliary power supply and a second  
switching element for performing a continuous power feed and  
a hold power feed from said main power supply, are connected  
in parallel to said electromagnetic solenoid; and a back-flow  
prevention diode, which prevents inflow of said rapid power  
10 feed, is connected in series to said second switching element.

6. The control device of a fuel injection valve according to claim 1,

wherein said first switching element and said second  
15 switching element are connected in series to said  
electromagnetic solenoid; said first switching element and  
said second switching element are brought into conduction,  
thereby performing said rapid power feed; and said continuous  
power feed is performed when said first switching element is  
20 not in conduction and only said second switching element  
continues to be conductive.

7. The control device of a fuel injection valve according to claim 5, further comprising first comparison means for  
25 determining that a conduction current to said electromagnetic  
solenoid detected by said current detection means has exceeded  
a first threshold being a predetermined peak current value;

wherein said first comparison means outputs a first  
determination signal to bring said first switching element  
30 into OFF when said first comparison means determines said

threshold excess, and ends said rapid power feed.

8. The control device of a fuel injection valve according to claim 7,

5        wherein said valve-opening drive signal is generated in response to said valve-opening signal, as well as set to end during said valve-opening signal being continued; and a continuous power feed by means of said second switching element is applied to the electromagnetic solenoid during continuance  
10 of said open-valve drive signal after said first comparison means has determined that a conduction current has exceeded a threshold.

9. The control device of a fuel injection valve according  
15 to claim 8, further comprising: a second comparison means for determining that a conduction current to said electromagnetic solenoid detected by said current detection means has drops below a second threshold larger than the minimum current required for holding an open valve of the electromagnetic  
20 solenoid and outputting a second determination signal;

      wherein said third switching element is being OFF until a determination signal is outputted by said second comparison means after said valve-opening drive signal has ended.

25        10. The control device of a fuel injection valve according to claim 9,

      wherein said conduction control means includes holding current control means for controlling current at the time of said hold power feed; during a time period from ending said  
30 valve-opening drive signal until ending of said valve-opening

signal, said holding current control means detects a lower limit corresponding to a minimum current value required for holding an open valve of said fuel injection valve, and an open-valve holding current upper limit larger than said lower  
5 limit by a predetermined value to perform an ON/OFF control of said second switching element, and performs an open-valve holding of said fuel injection valve; and during a time period from outputting the determination signal by means of said second comparison means until ending said valve-opening signal,  
10 said third switching element is held in an ON state.

11. The control device of a fuel injection valve according to claim 7, further comprising at least one of first and second comparison amplifiers for comparing outputs from said current  
15 detection means;

wherein said first comparison amplifier is constituted of a positive feedback circuit that outputs an operation signal when a conduction current to said electromagnetic solenoid exceeds said first threshold, thereby establishing said first  
20 determination signal, and stops an operation signal in the case of dropping below said second threshold, thereby establishing said second determination signal; said first comparison amplifier acts as an alternative of said first comparison means and second comparison means; said second  
25 comparison amplifier is constituted of a positive feedback circuit that outputs an operation signal when exceeding a threshold corresponding to said open-valve holding current upper limit, and stops an operation signal to perform the ON/OFF control of said second switching element when dropping below  
30 said minimum current value necessary for holding said

open-valve; and said second comparison amplifier acts as an alternative of said holding current control means.

12. The control device of a fuel injection valve according to claim 5, further comprising:

auxiliary power supply error detection means for detecting that an output voltage from said auxiliary power supply does not reach a predetermined value after a predetermined time period has passed since turning on an electric power from said main power supply, and outputting an error signal; and

auxiliary power supply error processing means for extending a valve-opening time period by making an end time of said valve-opening drive signal later or making an output time of said valve-opening signal earlier when said auxiliary power supply error detection means outputs an error signal.

13. The control device of a fuel injection valve according to claim 5, further comprising:

rapid power feed error determination means for performing an error determination when a conduction current to said electromagnetic solenoid does not exceed said first threshold after a predetermined time period has passed from ON of said first switching element; and

rapid power feed error processing means for extending a valve-opening time period by making an end time of said valve-opening drive signal later or making an output time of said valve-opening signal earlier when said auxiliary power supply error detection means outputs an error signal.'

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14. The control device of a fuel injection valve according to claim 1,

wherein said fuel injection valve is provided individually at each cylinder of a multi-cylinder internal combustion engine; and said auxiliary power supply is commonly  
5 used as a power supply for the rapid power feed to the electromagnetic solenoid of a plurality of said fuel injection valves.

10 15. The control device of a fuel injection valve according to claim 5,

wherein said fuel injection valve is provided individually at each cylinder of a multi-cylinder internal combustion engine; said first switching element, said second  
15 switching element and said current detection means are commonly used with respect to a pair of electromagnetic solenoids that performs a valve-opening operation alternately at regular intervals; and said third switching element is connected in series to each electromagnetic solenoid.

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16. The control device of a fuel injection valve according to claim 15, further comprising element error detection means for outputting an error determination signal when a detection  
current value by means of said current detection means is  
25 excessively large,

wherein said element error detection means stops operations of said first switching element and second switching  
element connected commonly to a pair of electromagnetic solenoids, and said third switching element connected in series  
30 to each electromagnetic solenoid when said element error



detection means determines that a detection current value is excessively large.

17. The control device of a fuel injection valve according  
5 to claim 16,

wherein said element error detection means comprises short circuit error detection means, and said short circuit error detection means outputs a short circuit error determination signal when a building-up differential value  
10 of a detection current by means of said current detection means is excessively large, when current of said rapid power feed is excessively large, or when a holding current is excessively large at the instant of operation start of the feedback control means for controlling feedback of said hold power feed.

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18. The control device of a fuel injection valve according  
to claim 16,

wherein said element error detection means comprises disconnection error detection means, and said disconnection  
20 error detection means outputs a disconnection error determination signal when said current detection means cannot detect a current in a state that any of said first switching element, said second switching element or said third switching element should be ON, or when a current value at the time of  
25 said rapid power feed is excessively small, and when any surge voltage is not generated across said third switching element at the time of opening circuit of said third switching element.

19. The control device of a fuel injection valve according  
30 to claim 17,

wherein said element error detection means comprises an alarm display, and when said short circuit error detection means outputs a short circuit error determination signal, said alarm display displays an alarm in response to said signals.

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20. The control device of a fuel injection valve according to claim 18,

wherein said element error detection means comprises an alarm display, and when said disconnection error detection  
10 means outputs a disconnection error determination signal, said alarm display displays an alarm in response to said signals.